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OVIPOSITION BY *ALEUROCANTHUS WOGLUMI* ASHBY (HOMOPTERA: ALEYRODIDAE) AS CORRELATED WITH LEAF CHARACTERISTICS

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Abstract.—The correlation between 34 chemical and physical attributes of 23 plant species and oviposition by female citrus blackfly, *Aleurocanthus woglumi* Ashby (Homoptera: Aleyrodidae) was examined. Three individual factors, the relative levels of cysteine and methionine, and the tensile strength of the leaves had significant correlations with oviposition, but no single factor accounted for more than 32% of the variation in *A. woglumi* oviposition. A multiple regression using the levels of cysteine, methionine, glucose, fructose, and percentage nitrogen gave the best fit and accounted for 62% of the observed variation in *A. woglumi* oviposition.

Key Words.—Insecta, Aleyrodidae, *Aleurocanthus woglumi,* cysteine, methionine, glucose, percentage nitrogen, tensile strength

Despite the increasing importance of whiteflies, especially *Bemisia tabaci* (Gennadius), as crop pests (Dittrich et al. 1985), little is known about how these insects select plants upon which to oviposit. Whiteflies orient towards any object reflecting light of the proper wavelength. Determination that the object is acceptable for oviposition occurs after the female contacts the surface and may involve mandibular probing of the plant cuticle and underlying tissues; see Lenteren & Noldus (1990) and the references therein. Almost nothing is known about the post-alighting factors affecting oviposition by whiteflies.

This paper determines the correlation between oviposition by the citrus blackfly (CBF), *Aleurocanthus woglumi* Ashby and 34 chemical and physical attributes of leaves from 23 host plants in 12 families (Table 1). I examine which factors are related to oviposition singly and in combination.

Materials and Methods

All tests utilized the youngest mature growth from each plant species (Table 1) (Dowell & Cherry 1981). Ten leaves were taken from each of three plants and immediately placed in plastic bags. The leaves were weighed within 10 min of being picked. They were then tested with a Li-Cor Area Meter® to measure their area, placed in paper bags and held for 10 days in a drying oven at 50° C. After being reweighed they were ground in a Wiley mill prior to micro-kjeldahl analysis to determine their percentage of nitrogen (%N) and phosphorus (%P).

A second set of leaves taken from the same plants was analyzed for glucose and fructose levels using the colorimetric techniques of Helbert & Brown (1955), and for the presence of amino acids using thin-layer chromotography (TLC) of dansyl derivatives as described by Barcelon (1982). Split samples were used as internal controls for these analyses. The relative concentrations of each amino acid was estimated from the TLC plates as follows: not present = 0, faint glow = 1, moderate glow = 2, strong glow = 3 (Barcelon 1982, Barcelon et al. 1983).

The tensile strength of the leaves was determined as follows. Two pieces of plastic 6.4 mm thick were drilled with a 1 mm diameter hole. Individual leaves

Table 1. Selected leaf characteristics and ovipositional attractiveness of the test plants.

Plant[a]	Ovipositional attractiveness[b]	Cysteine/ methionine[c]	Glucose/fructose[d]	%N
Ardisia	3	3/0	1.17/0.51	1.6
Avocado	0.08	2/2	2.53/1.83	1.9
Black sapote	1	2/2	4.7/9.84	1.8
Box-orange	5	0/0	0.96/1.09	2.0
Citrus	100	0/2	2.13/0.80	2.4
Coffee	0.2	0/0	3.50/1.21	3.0
Gardenia	0.04	2/0	3.70/11.58	1.9
Ixora	0.5	3/2	1.83/0.77	1.6
Japanese boxwood	0.5	2/0	NA/NA	1.6
Kumquat[e]	67	0/2	4.55/1.18	2.7
Limeberry	6	3/0	3.00/11.28	2.2
Loquat	17	0/0	1.44/0.65	1.6
Mango[e]	72	0/2	2.18/0.52	1.5
Marlberry	10	0/0	1.11/0.42	1.4
Myrsine	3	2/0	1.09/0.44	1.6
Pink trumpet[e]	65	1/0	3.69/0.58	1.9
Prickly ash	0.4	1/0	1.59/0.19	1.4
Sapodilla	0.6	3/0	0.95/1.03	1.5
Schinus	1.4	2/2	2.20/7.36	2.2
Silver trumpet	3	0/2	1.18/0.86	1.8
Surnam-cherry	1	3/0	1.30/0.25	1.9
Toog	0.02	3/0	1.68/0.28	1.7
Wampi	17	2/0	2.21/0.36	1.5

[a] See Dowell & Steinberg (1979) for scientific names and families.

[b] All values relative to citrus which is set at 100. Data from Dowell & Steinberg (1979), and Howard & Neel (1977).

[c] Relative value with 0 = not present, 1 = faint glow on TLC plate, 2 = moderate glow and 3 = strong glow (Barcelon 1982).

[d] μg/mg wet weight.

[e] As attractive as citrus to ovipositing CBF (Dowell & Steinberg 1979).

were sandwiched between these plastic blocks and the unit was held together by bolts secured by wing nuts. A 1 mm diameter metal rod with a smooth, flat end face was placed through the hole in the upper block and rested upon the upper surface of the leaf. Steel spheres (3 mm diameter) were individually placed in a plastic cup atop the rod until the rod pushed through the leaf. The spheres were then removed and weighed. The test was repeated three times on each of three leaves per plant, and an average was taken.

Data on the attractiveness of the test plants to ovipositing CBF were taken from Dowell et al. (1979) and Howard & Neel (1978). For each test, the number of egg spirals laid on the citrus plants was set at 100. Oviposition on the other plants was standardized relative to this value to compensate for widely differing numbers of CBF present during the exposure periods. These values were then subjected to single and multiple regression analyses (Little & Hills 1978) against the foliar chemical and physical attributes measured above.

RESULTS

There was a 5000-fold difference in the attractiveness of the test plants to ovipositing CBF with citrus the most attractive plant and toog the least attractive

(Table 1). I tested the accuracy of these data by regressing the ovipositional attraction of 12 of the test plants against the percentage of the plants found infested with CBF in field surveys of dooryard plants in Broward County, Florida from 20 Jul to 16 Sep 1977. The field hosts were citrus (64.2% infested), kumquat (50.0%), mango (47.9%), pink trumpet (44.4%), Surinam-cherry (14.6%), loquat (12.5%), gardenia (7.3%), schinus (6.2%), ixora (0.7%), and toog, coffee and sapodilla all at 0% infested. The correlation is highly significant ($r^2 = 0.97$; F = 294.7; df = 1, 9; $P < 0.0001$; $y = 3.72 + 0.63x$) indicating that the values for ovipositional attraction in Table 1 strongly reflect the actual field preferences shown by female CBF in Florida.

The relative levels of cysteine and methionine, and the tensile strength of the leaves were the only individual host plant attributes significantly correlated with oviposition by CBF (Table 2). CBF adults congregate on the newest flush growth of citrus but they do not oviposit on nonteneral leaves. Oviposition occurs primarily on the youngest mature growth (Dowell & Cherry 1981). Walker (1987, 1988) has shown that another whitefly, *Parabemisia myricae* (Kuwana), which oviposits only on the newest growth, is able to distinguish between the cuticles of new versus mature citrus leaves. As citrus leaves mature becoming teneral, they expand, darken, and become rigid and stronger. Female CBF could theoretically "measure" leaf maturity by determining how hard it is to probe the leaf; that, however, is unlikely. It is more likely that tensile strength reflects other changes in leaf chemistry that occur in the cuticle as the leaf matures (Freeman et al. 1979) and that these are what might be perceived by the whitefly.

Among the leaf factors analyzed, no single attribute accounts for more than 23% of the observed variation in CBF oviposition. Several attributes found to be important in other insects (%N, glucose/nitrogen ratio) explain little of the observed variation in CBF oviposition (Table 2).

The only attribute significantly correlated with the survival of immature CBF, tissue density (mg wet tissue/cm^2 leaf surface) (Dowell & Steinberg 1990), is not significantly correlated with oviposition (Table 2). Dowell & Steinberg (1979) previously showed that there is no relationship between the attractiveness of plants to ovipositing CBF and the subsequent survival of the nymphs. Our results and those of Dowell & Steinberg (1979) show that different leaf characters affect the two processes.

Multiple regression analysis found that the levels of cysteine, methionine, glucose, fructose, and %N are the key attributes correlated with oviposition by female CBF ($r^2 = 0.62$; F = 4.93; df = 5, 15; $P = 0.007$). Inclusion of tensile strength does not alter the correlation coefficient indicating that the relationship shown in Table 2 either is spurious or that the tensile strength of plant leaves affects CBF oviposition at a different point in the process than internal leaf chemistry. The multiple regression explains 62% of the observed variation in CBF oviposition.

The use of multiple regression analysis highlighted several important points. No single attribute explained as much of the observed variation as the use of multiple attributes. There is little correlation between the importance of the attributes when viewed singly and when viewed in groups. Based upon the data in Table 2, tensile strength should have been an important factor in a multiple regression, but it was not. Instead, three factors that have insignificant individual correlations (glucose, fructose, %N) are important factors in the multiple regres-

Table 2. Correlation coefficients of leaf characters and ovipositional attractiveness of the test plants.

Leaf character	Correlation coefficient	P[d]
Cysteine[a]	−0.57	0.006
Tensile strength	0.47	0.024
Methionine	0.43	0.048
Glucose[b]	0.29	0.196
%N	0.28	0.189
Fructose[b]	−0.23	0.297
Glucose/nitrogen ratio[b,c]	0.22	0.325
Tissue density	0.22	0.325
%P	−0.18	0.424
Percentage water	−0.17	0.432
Total sugars[b]	−0.11	0.613
Area	0.002	0.990

[a] No other single amino acid or group of amino acids had significant correlation coefficients.
[b] $n = 22$, no sugar data for Japanese boxwood.
[c] % dry weight/% dry weight.
[d] As determined with ANOVA (Little & Hills 1987).

sion. Willig et al. (1986) found a similar situation when they examined the relative importance of various mensural characters in univariate and multivariate morphometric analyses.

DISCUSSION

Kogan (1977) has postulated that for polyphagous homopterans, such as whiteflies, long-range attractants should be absent and that if ovipositional stimulants are present, they should be ubiquitous compounds such as amino acids, sugars, and water. He further theorizes that close-range repellents may be present. My data support Kogan's concept.

After landing, female CBF are able to identify unacceptable hosts (e.g., fern) and very poor hosts (e.g., gardenia) within 2–13 sec (Dowell 1979). This may be an insufficient period for the female to probe through the cuticle (Walker 1987) suggesting that some contact repellency occurs. Whitefly species in six genera have seven pairs of mechanoreceptors and chemoreceptors on their rostrums and are able to taste the surface of leaves prior to stylet penetration (Walker & Gordh 1989). This may be the point in the ovipositional process where leaf toughness (representing mature leaf cuticles) is important. If the female is not "repelled," she begins to probe the leaf. At this point the female begins to evaluate the factors identified in Table 2: cysteine, methionine, glucose, fructose, and nitrogen levels. If these are acceptable, she then oviposits an egg spiral. These chemical factors account for 62% of the observed variation in oviposition by CBF females.

I postulate that the more attractive a plant is to a population of ovipositing CBF, the greater is the relative frequency of genes conferring acceptance or tolerance of the compounds in the leaf cuticle and sap. Under this quantitative genetic concept genes allowing oviposition on kumquat, mango, and pink trumpet are 65–72% as common as those allowing oviposition on citrus, or at least their additive summation effects provide such a degree of relative influence. Hosts such as avocado, gardenia, and toog appear to have leaf cuticle or sap repellents for which almost no CBF have tolerance. Once past the cuticle, the ubiquitous compounds postulated by Kogan (1977) became important in determining whether oviposition occurs.

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